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The Stock Size of Nature Capital

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ABSTRACT

This paper presents a simple method for estimating environmental capital (KN) stock. The display employs the same metric as that used for manufactured capital (KM) stock in the statement of national accounts. The method is an adaptation the perpetual inventory method, but in a reverse order that is based on depreciation instead of accumulation. Besides depreciation, the stock estimates also rely on resilience factor.

1. INTRODUCTION

Capital theory in economics owes its origins to the conceptualization of nature as capital. Fisher's (1904) seminal paper, which is perhaps the cornerstone of the economics of capital, builds on the premise that nature is durable stock that generates flows of services – the extraction of which results in degradation. That is, the three essential properties of capital, namely durability, generation of service flows and depreciation are drawn from observations pertaining to natural capital – hereafter termed environmental capital (KN). A basic premise in environmental economics is that KN is a determinant of national income (Y) besides labor (L) and manufactured capital (KM); (Thampapillai and Sinden 2013, Thampapillai 2014). With reference to factor utilization for explaining Y, the distinction between KN and KM is that the utilization of KM is based on the accumulation of stock whilst that of KN involves the depletion of stock.

Nevertheless, standard economic theory confines its attention to KM and fails to acknowledge KN despite its essential role in supporting economic systems. It is in order to demonstrate the foundational importance of KN that several studies have attempted the monetary valuation of KN. Most of the attempts have rested on the concepts of willingness to pay and willingness to accept in microeconomics. Such attempts have invariably centered on methods associated with contingent valuation; (Costanza et al. 1997, 2014). This paper offers an alternative approach to estimate the stock size of KN. It draws on an accounting method employed with reference to KM stock accumulation in macroeconomics. This method, the perpetual inventory method (PIM), enables the quantification of the stock size of KM that could have existed at the initial time period of a time series dataset. Hence, in adapting the PIM to the context of KN, the question posed is: *What could have been the stock size of KN at the start of a specific time series in macroeconomic analyses?*

The paper is structured as follows. The next section provides a brief description of the PIM This is followed by its adaptation to the context of KN and an empirical illustration with reference to the Australian continent. The stock size of KN with reference to certain endowments such as forests and minerals can be ascertained by recourse surveys of geographic information systems and geological records. This paper concerns KN endowments that cannot be readily quantified. These are primarily KN sinks and here an air shed is chosen for illustrative purposes.

2. THE PERPETUAL INVENTORY METHOD (PIM)

In the statement of national accounts, estimates of KM are generally displayed in constant dollars, thereby enabling diverse items of KM to be aggregated into a single numerical value. The PIM defines the size of KM stock at the start of a given time period in terms of the stock that prevailed at the start of previous period. This previous period stock is then adjusted for investments and depreciation that would have occurred during the previous period. For example the stock of KM in time t would be described as:

$$KM_t = KM_{t-1} + I_{t-1} - \delta KM_{t-1} \qquad (1)$$

In (1) δ usually represents a fixed rate of depreciation of KM stock. Consider now the initial time period (t = 0) and the period immediately following it, that is (t = 1). The application of (1) with reference (t=1) will be as follows:

$$KM_1 = KM_0 + I_0 - \delta KM_0 \qquad (2)$$

And when rearranged, (2) could be written as:

$$KM_1 - KM_0 + \delta KM_0 = I_0 \qquad (3)$$

The PIM assumes that the difference ($KM_1 - KM_0$), can be approximated by recourse to an average annual rate of growth of investment in the time series dataset. Suppose that this rate of growth is θ. Then ($KM_1 - KM_0$) equates to (θKM_0), and the stock of KM that would have existed in the initial period becomes:

$$KM_0 = \frac{I_0}{(\theta + \delta)} \qquad (4)$$

In (4), the coefficient θ is usually estimated on the premise that investments grow at an exponential rate over time; that is $I_t = Ae^{\theta t}$ and hence $[dI_t/dt] = \theta$. The coefficient δ is typically assumed to be the result KM stock having an average life 30 – 40 years and hence is assigned fixed values ranging between (1/30) and (1/50).

3. ADAPTING THE PERPETUAL INVENTORY METHOD FOR KN

As indicated, the utilization of KN towards the determination of Y is primarily based on the depreciation of existing KN stocks. Examples of such stocks include forests, mineral deposits, soils and KN sinks such as air sheds and bodies of water. As indicated, measurement difficulties persist with specific KN endowments that are primarily environmental sinks; for example, air sheds and oceans. It is further reasonable to assume that with such endowments, the net changes in stock during any given time period is one of depreciation.

An adapted version of the PIM could be used estimate the stock size of specific KN endowments in the same units of measurement as those employed for KM in the statement of national accounts. That is, constant base year prices. This measurement would necessitate the valuation of the depreciation of KN stocks in those same units of measurement. Examples of such valuations do exist. For example, costs of air pollution abatement (at constant prices) have been regarded as a proxy for the depreciation of the air shed (Daly and Cobb 1989; Thampapillai 2012), whilst the net loss in forest area has been approximated to a loss in either land or stumpage value (Repetto et al. 1989). On a similar vein, the added costs of fertilizer usage have been used as a proxy for the loss of soil fertility (Thampapillai, Xun and Tan 2010) and the value of mineral output (net of investment) as a measure of depreciation of mines (Hartwick 1990, Hartwick and Olewiler 1986). Time series estimates of such depreciation costs would enable the elicitation of average annual rates depreciation (δ_{KN}). As indicated, this paper concerns the estimation of the stock size of an air shed.

Further, one also needs to adjust (δ_{KN}) by weighting it using a resilience factor (ρ). This factor takes on a value between zero and one; that is ($0 \leq \rho \leq 1$). If KN stock utilized would restore it self completely, then ($\rho = 1$) implying complete resilience. At the other extreme, ($\rho = 0$) implies complete non-resilience. Hence the net depreciation would be given by [δ_{KN} * (1 - ρ)]

Consider now the adaptation of (2) above to the context of KN stocks. The definition of KN stocks in a given year (t) namely (KN_t) would be made with reference to KN stocks of the previous year (KN_{t-1}):

$$KN_t = KN_{t-1} - [\delta_{KN} * (1 - \rho)] * KN_{t-1} \qquad (5)$$

Hence it follows that

$$[\delta_{KN} * (1 - \rho)] * KN_{t-1} = KN_{t-1} - KN_t = D_{t-1} \qquad (6)$$

In (6), D_{t-1} is the observed estimate of KN depreciation in year (t-1), and hence:

$$KN_{t-1} = \frac{D_{t-1}}{\delta_{KN} * (1 - \rho)} \qquad (7)$$

When the KN endowment considered is an air shed, D_{t-1} then represents the costs of air pollution abatement that were recorded for year (t-1) and δ□□ □□ average annual rate of growth of these pollution abatement costs.

As an extension of (6) above, consider the comparison of the initial year (t = 0) with the terminal year (t = T). This comparison could be explained as follows:

$$T * [\delta_{KN} * (1 - \rho)] * KN_0 = KN_0 - KN_T = \sum_{t=0}^{T} D_t \qquad (8)$$

T represents the number of years between the initial year and the terminal year. Hence the minimum stock size of KN that could have existed in (t = 0) is:

$$KN_0 = \left[\frac{\sum_{t=0}^{T} D_t}{[T * \delta_{KN} * (1 - \rho)]} \right] \qquad (9)$$

In (8) – (9), if ($\rho \rightarrow 1$) then, ($KN_0 \rightarrow \infty$). The major challenge herein would be the estimation of ρ. This would rely on scientific information; for example see Carpenter et al.

2001. Whilst several air quality indices have surfaced recently (Office of Environment and Heritage 2015), time series data is sparse. A possible proxy for ρ could be a ratio of the number of days in a year specific important emission standards were not exceeded.

4. EMPIRICAL ILLUSTRATION

The method is illustrated with reference to Australia's air shed as the KN endowment. The cost of abating CO2 emissions was nominated as a proxy for the depreciation of the air shed. Time series data on CO2 emissions for the period 1960 – 2013 was obtained from World Development Indicators (2015). The unit cost of abating CO2 was assumed to be $130 (Australian Dollars) following the Stern (2006) Report. This cost was then trended to display a time series of real unit cost values by recourse to the trend of Real Gross Value Added at Factor Cost by keeping 2006 as the base year. The resulting estimates of annual depreciation (Table-A1 in Appendix) enable the elicitation of the average annual rate of depreciation, namely δ_{KN}.

Because of sparse data, several assumptions were made with reference to the resilience coefficient ρ. Consequently the results displayed here are more illustrative than otherwise. Limited time series (1998 – 2009) data was available on the number of days the acceptable level of ozone concentrations and smog were exceeded; (Australian Bureau of Statistics 2010). Hence a ratio in terms of the number of days such excesses did not occur in a given year was nominated as a proxy for ρ. A review of the 12-year period (1998-2009) revealed that the average number of days of exceedence per year was 12. Further the review did not display a clear downward trend in the number of such days of exceedence above accepted levels. Hence it was assumed that the average number of days of exceedence per year would remain the same for the period 1960 – 2013 as well. The value of ρ then is ((365-12)/365), namely 96.7 percent. The estimation of KN_0, namely the size of KN that would have been available to the Australian economy in 1960, is illustrated in Table-1.

Table -1: Estimation of KN Stock in 1960

$\sum D_t$ (1960 - 2013) ($)	1.20304E+12
δ_{KN}	0.0569
ρ	0.967
T	54
KN_0 (1960)	1.19092E+13
KN_T (2013) = $KN_0 - \sum D_t$	1.07062E+13

As indicated in Table-1, the size of KN (air shed) that could have existed in 1960, in national income accounting terms, is approximately 12 Trillion (2006) Australian Dollars. The cumulative KN utilization over 1960 – 2013 is nearly 1.2 Trillion Australian Dollars. This means that approximately $10.7 Trillion dollars worth of KN remained available in 2013. That is, in cumulative terms, the KN stock considered here, namely the air shed has depreciated by roughly 10 percent over the 54-year period.

Yet another comparison that can be ascertained from the data is the ratio KN/KM. In 1960 this ratio was 24.2. That is, KN was 2400 per cent larger in 1960 than the accumulated stock of KM as elicited from the PIM. In 2013, this percentage excess was only 190 percent.

5. CONCLUDING REMARKS

The common perception is that the size of KN stocks such as air sheds and oceans are undefined. The simple analytics presented here permits the appreciation of finite limits to endowments, which are mistakenly assumed to be infinite. The values presented here do hinge on the assumptions – specifically the resilience coefficient (ρ). Despite the tenuous nature of the assumptions, the paper presents a simple framework, the analytics of which can be rendered robust with improved scientific data.

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APPENDIX

TABLE-A1: CO2 EMISSIONS AND DEPRECIATION COST

Year	CO2 emissions (kt)	Price of CO2 ($)	D_t ($)
1960	88202.35	31.06	2.74E+09
1961	90589.57	32.02	2.90E+09
1962	94912.96	33.01	3.13E+09
1963	101029.52	34.03	3.44E+09
1964	108979.57	35.09	3.82E+09
1965	120967.00	36.17	4.38E+09
1966	120332.61	37.29	4.49E+09
1967	129265.42	38.44	4.97E+09
1968	134622.90	39.63	5.34E+09
1969	142257.60	40.86	5.81E+09
1970	147618.75	42.12	6.22E+09
1971	152774.55	43.42	6.63E+09
1972	157486.65	44.77	7.05E+09
1973	170992.21	46.15	7.89E+09
1974	172356.33	47.58	8.20E+09
1975	175883.99	49.05	8.63E+09
1976	174244.84	50.57	8.81E+09
1977	187787.07	52.13	9.79E+09
1978	202015.03	53.74	1.09E+10
1979	205069.64	55.41	1.14E+10
1980	220746.07	57.12	1.26E+10
1981	230360.94	58.89	1.36E+10
1982	234119.62	60.71	1.42E+10
1983	225003.45	62.58	1.41E+10
1984	236594.84	64.52	1.53E+10
1985	241229.93	66.52	1.60E+10
1986	239964.81	68.57	1.65E+10
1987	256106.95	70.69	1.81E+10
1988	261145.41	72.88	1.90E+10
1989	277771.58	75.13	2.09E+10
1990	287331.45	77.46	2.23E+10
1991	281530.26	79.85	2.25E+10
1992	294456.43	82.32	2.42E+10
1993	302116.80	84.87	2.56E+10
1994	303957.63	87.49	2.66E+10
1995	307433.95	90.20	2.77E+10
1996	329259.93	92.99	3.06E+10
1997	333623.66	95.87	3.20E+10
1998	346912.87	98.83	3.43E+10
1999	325523.26	101.89	3.32E+10
2000	329604.63	105.04	3.46E+10
2001	324859.53	108.29	3.52E+10
2002	341001.66	111.64	3.81E+10
2003	346476.50	115.09	3.99E+10
2004	348757.37	118.65	4.14E+10
2005	362684.64	122.32	4.44E+10

Year	CO2 emissions (kt)	Price of CO2 ($)	D_t ($)
2006	371214.08	126.10	4.68E+10
2007	377235.29	130.00	4.90E+10
2008	387634.90	133.90	5.19E+10
2009	395093.58	137.92	5.45E+10
2010	373080.58	142.05	5.30E+10
2011	351067.58	146.32	5.14E+10
2012	329054.58	150.71	4.96E+10
2013	307041.58	155.23	4.77E+10